Haptic Thermal Interface: A New Technology for Supporting Presence in Multimodal Virtual Environments?

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Abstract

This paper describes how the thermal user interface system can be integrated into other input devices to develop multimodal user interfaces that present multisensory feedback. Multimodal virtual environments supporting both haptic force and haptic thermal feedback will allow researchers to investigate a wide range of research issues involved in presence study. Among presence-related research questions are 1) what role the additional thermal feedback has for presence in multimodal virtual environments, 2) whether it affects task performance in various task environments, 3) what kinds of design principles and guidelines of multimodal user interfaces should be considered to improve the user's perceived presence, and 4) how those principles and guidelines can be applied to the use of multimodal user interfaces in various applications.

1. Introduction

The use of haptic devices as an interaction tool provides users with a new and interesting sensorial experience, *the sense of touch*, through tactile and force feedback. Despite such powerful sensory inputs as tactile and force feedback, however, haptic interface systems are still in an early stage of accomplishing a high degree of realism. One of the haptic elements missing is the ability to present thermal information such as the thermal conductivity and temperature of an object being manipulated. Thermal feedback should be incorporated into haptic interface systems and multimodal virtual environments to deliver a more convincing and intuitive presence in virtual environments or teleoperation systems.

Much more studies are still needed to understand how thermal modality can be used to increase richness of sensory information [1, 2] in virtual environments. It would be interesting to investigate what role the additional thermal feedback has for presence in virtual environments, and whether it affects task performance in various task environments. In addition, more studies need to be done on the effects of multimodal virtual environments supporting multiple modalities including visual, audio, haptic force, and haptic thermal on perceived presence. To help address these two issues, the HCI research team at the University of Arkansas has developed and evaluated thermal interface systems that can present thermal information of an object being manipulated to the human operator interacting with VEs accurately and with no overt time delay [3, 4].

This study reports our ongoing efforts to develop advanced multimodal user interfaces for virtual environments that can provide the user with multiple sensory feedbacks. First, this study will demonstrate how the thermal interface system developed in my previous study [3] can be integrated with other input devices to present multiple sensory feedbacks including thermal feedback. This study concludes with a description on a series of empirical experiments that we are planning to conduct in order to investigate what role the additional thermal feedback has for presence in multimodal virtual environments, and whether it affects task performance in various task environments.

2. Multimodal Interface: Visual-plus-Thermal

***Integration with optical mouse*:** The manipulator end of the thermal interface system can be integrated into a computer mouse to develop a multimodal user interface that can provide both visual and thermal feedbacks to the user interacting with virtual environments. Considering the structure of the mouse system and the way the user operates it, there are two mechanisms to integrate the thermal feedback system onto the mouse: 1) the thumb and the ring finger touch (finger-strategy); 2) the palm touches (palm-strategy). Figure 1 shows an example of the finger-strategy integration, which allows users to position the manipulator where their thumb would lie with normal use of the mouse. This creates a situation where they could use the mouse to initiate thermal change and then could be sensed on the same hand without releasing our grip or moving our hand.

To evaluate the effectiveness of the multimodal user interface system for virtual environments, a three-dimensional desktop virtual environment application was developed in which the user can feel the warmth of objects when touching. For the virtual environment, an office area model was used, consisting of three rooms and various objects such as office furniture and equipments users would expect to find.

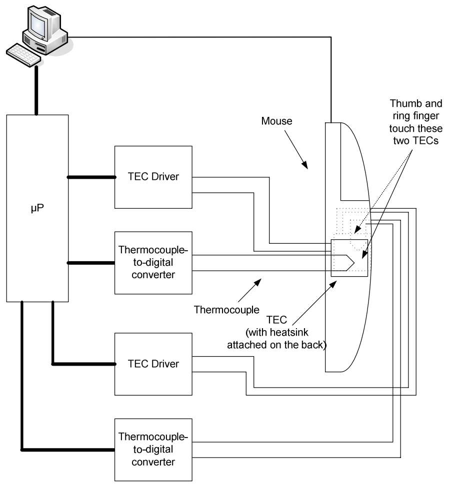

Figure 1. Structure of finger-strategy integration

Temperature changes would be committed when the multimodal interface system entered a 3D object. Our previous work showed promising results that additional thermal feedback helped participants' object identification, as well as enhanced their perceived presence in a 3D desktop virtual environment [4].

4. Multimodal Interface: Thermal-plus-Haptic

Integration with haptic system: The manipulator end of the thermal system can also be integrated into an existing haptic system (e.g., PHANToM Omni, SensAble Technologies). The user then can hold a spherical object and feel both force and thermal feedback while interacting with the VEs. A 3D desktop VE application was also developed to evaluate the system's effectiveness, in which the user can receive thermal as well as haptic feedback (Figure 2).

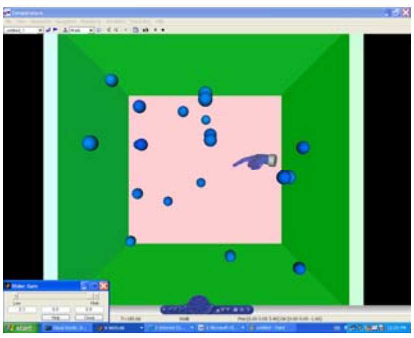

Figure 2: Haptic virtual environment application

Using PHANToM Omni (SensAble Technologies) and proSENSE software (Handshake VR Inc.), we have developed an application in which, through the multimodal user interface, the user can feel both changes in temperature of an object and the movement of its atoms (represented as haptic spheres) as its temperature changes, when experiencing physical properties of temperature and force [5].

Conclusions

This paper described how the thermal interface system can be integrated into other input devices to develop multimodal user interfaces that present multiple sensory feedbacks. Multimodal virtual environments supporting both haptic force and haptic thermal feedback allow researchers to investigate what the addition of thermal feedback and other sensorial feedbacks would contribute to the sense of presence and task performance in multimodal virtual environments.

Our future plan is to conduct a series of empirical experiments in order to investigate a wide range of research issues involved in presence study. Among presence-related research questions are 1) what role the additional thermal feedback has for presence in multimodal virtual environments, 2) whether it affects task performance in various task environments, 3) what kinds of design principles and guidelines of multimodal user interfaces should be considered to improve the user's perceived presence, and 4) how those principles and guidelines can be applied to the use of multimodal user interfaces in various applications.

During the past decades, we have assumed a strong relationship between the number of channels/sensory cues and the degree of presence. As Lombard and Ditton criticized [6], however, the relationship has not been fully investigated. The research questions proposed in this paper, which can be examined by using the multimodal user interface system supporting multiple sensory feedbacks, will help to prove the assumption.

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